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Study of Radioactivity Concentration in Air of Dhaka city

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ABSTRACT:

Air monitoring is a continuous process which is needed to monitor for knowing the concentration of radionuclides present in the air. During this study, forty air samples were collected from different areas such as Hazaribagh Tannery Area, Plastic Goli Islambagh, Sayedabad Bus Terminal etc. which have been evaluated using high resolution gamma-ray spectrometry at Atomic Energy Center (AEC), Dhaka. From the obtained results it is found that the radioactivity concentrations of ^{238}U, ^{232}Th and ^{40}K in the air samples varied from 3.93± 0.49 mBq/m^3 to 1784 ± 87.16 mBq/m^3, 0.0 to 399 ± 27.04 mBq/m^3, 0.0 to 256 ± 3.81 mBq/m^3 and the average values are 448 ± 16.09 mBq/m^3, 90.71 ± 8.56 mBq/m^3 and 97 ± 3.54 mBq/m^3 respectively. The artificial radionuclide such as ^{137}Cs was not observed. The construction of Rooppur nuclear power plant is going on in Bangladesh. The concentrations of different radionuclides in air particle of present study will be helpful to monitor and compare the concentration of radionuclides in air samples around Rooppur Nuclear Power Plant. The main purpose of the present research is to measure the radioactivity concentrations of different radionuclides in air particle which is helpful to establish the base line data.

Key words: Air particle, Radioactivity, Gamma spectrometry system and Dhaka city.

INTRODUCTION

Radioactivity is an omnipresent phenomenon in the environment, and naturally occurring radionuclides have always been present in our surroundings. One can distinguish between three different origins of natural radionuclides: primordial, decay products and cosmogenic. Primordial cosmogenic or anthropogenic radionuclides present in the ambient air are useful tracers for studying physical and health-related processes in the atmosphere [1]. Primordial radionuclides, like e.g. ^{40}K, have very long half lives (~105-109 years) and have been present in the crust of the Earth since its creation. Decay products are part of one of the three natural decay chains: the uranium, thorium, and actinide-series. Cosmogenic radionuclides are produced by cosmic radiation, through e.g. neutron capture. The most abundant of the cosmogenic radionuclides are ^{14}C and ^{3}H. However, in the case of radionuclides from the uranium and thorium series a special measurement and calculation procedures must be applied. The reason is the change in number of their atoms on a filter during sampling and counting, according to the law of radioactive decay for secular and transient parent-daughter equilibrium.

In the last century, mankind has started to contribute significantly to our radiation environment by the release of anthropogenic radionuclides, primarily from two different sources: atmospheric testing of nuclear explosive devices and releases from nuclear reactors. Radionuclides found in radioactive fallout include for instance ^{131}I, ^{133}I, ^{134}Cs, ^{137}Cs, ^{95}Zr, ^{141}Ce, ^{95}Nb, ^{132}Te. In the Chernobyl fallout, the radionuclides contributing most to human radiation exposure are ^{131}I and ^{137}Cs. On a worldwide scale the average contribution to human exposure from anthropogenic sources are about one order of magnitude lower than doses from natural radioactivity, but on a regional scale doses and dose rates can be very high [2].Maximum permissible dose (MPD) for non occupationally exposed individual is put at 1mSv/yr. At high doses, ionizing radiation is dangerous. It is therefore necessary to know the level of radiation within our living environment because of the health implications [3].Background radiation is the radiation constantly present in the natural environment of the Earth, which is emitted by natural and artificial sources. Natural radioactivity is wide spread in the earth's environment; it exists in soil, plants, water and air. Exposure of radiation mainly comes from natural radiation (85 %). The assessment of gamma radiation doses from natural sources is of particular importance because natural radiation is the largest

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contributor of external dose to the world population. The exposure of human beings to ionizing radiation from natural sources is a continuing and feature of life on earth inescapable. Throughout the history of life on earth, organisms have been continuously exposed to radiations from radio-nuclides produced by cosmic ray interaction in the atmosphere and radiations from naturally occurring substances that are spatially distributed in all living and non-living components of the biosphere. Knowledge of the concentrations and distributions of the radionuclides in air particles are of interest since they provide useful information on the monitoring of environmental contamination by radioactive materials in the natural environment. Enhanced levels of radioactivity in particular areas can arise due to the discharges of radioactive nuclides following human intervention [4]. A determination of the concentration and the distribution of air particle radioactivity is essential in establishing reference data, allowing the observation of possible future changes due to future radiological contamination [5]. Therefore, radioactivity determination of particulates collected on filters of High Volume Air Sampler is a standard technique for monitoring airborne activity [6,7,8]. After the desired collection period the activity of deposited radionuclides can be measured by γ-spectrometry for ^{7}Be, ^{212}Pb, ^{212}Bi, ^{214}Pb, ^{214}Bi. Spectrometric methods do not require additional sample preparation and allow one to find aerosol activity by a simple filter measurement. Throughout the history of life on earth, organisms have been continuously exposed to radiations from radio-nuclides produced by cosmic ray interaction in the atmosphere and radiations from naturally occurring substances that are spatially distributed in all living and non-living components of the biosphere [9].

The primary purpose of the study is to monitor the concentration of different radionuclides in air particle. The data obtained from the study will be helpful to predict amount of radiation exposed by the City dwellers. Moreover it will help us to compare with the previous data and whether the radionuclides are increasing or decreasing in the air of Dhaka City. Health Physicists can use this data to measure the harmful effect of natural and artificial radiations. Furthermore, the result of this study will also help to compare the concentration of radionuclides in air samples around Rooppur Nuclear Power Plant.

MATERIALS AND METHOD

Study Areas

The concentration of different radionuclides present in the air in the following areas of Dhaka City was monitored using Air monitor device and later synthesized using high purity Germanium detector. Around 50% of the locations are in congested area of the city such as Bus Terminal, Industrial Areas and the other 50% locations are in areas with natural serenity such as Park, so that a comparison study can be done. This also helps to predict the contribution from Motor Vehicles and Industrial Poisons. During this study, forty air samples were collected from different places of Dhaka city which have been listed in Table 1.with sample identification (ID) and shown in figure 1, 2, 3&4.

Collection and Preparation of Samples

Radioactive samples have been collected on different days at different times from BRTC central bus terminal, Hazaribagh tannery area,Plasticgoli,Mohakhali, Gabtoli Bus Terminal, islambagh, Motijheel , farmgate etc. 40 measurements have been taken at different times started from 10th December 2015 to 25thFebruary 2016 on random basis. Air particulate collection has been performed by suction of indoor air through filter paper using portable Staplex air sampler. Before collecting air particulates on filter paper, air filter weight has been measured. The flow rate of the Staplex air sampler is 30ft^3/min and the sampler run for 60 minutes. At the end of sampling, the filter has been packed in plastic bags as 'packetsample' and measurement geometry used for gamma-ray spectrometry.

Experimental Procedure

Each sample was measured with a gamma-ray counting system, a high resolution HPGe coaxial

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detector (EG&G ORTEC) coupled with a Silena Emcaplus Multichannel Analyzer (MCA) and associate microprocessors. The effective volume of the detector was 83.47 cm^3 and energy resolution of the detector was found to be 1.69 keV at 1332 keV energy peak of ^{60}Co (Figure 2) with a relative efficiency of 19.6%. The detector was shielded with copper ring (2 mm) at the side and lead (76.2 mm) at the side and the top for reducing the background radiation level. To minimize the effect of the scattered radiation from the shield, the detector is located at the center of the chamber. Then the sample was placed over the detector for counting. The spectra were either evaluated with the computer software program Maestro (EG&G ORTEC), or manually with the use of a spread sheet (Microsoft Excel) to calculate the natural radioactivity. The efficiency of the detector for different radionuclides of interest of different energies were determined by standard source Eu-152 and different energies such as 122, 245, 344, 411, 444, 779, 963, 1086, 1112 and 1408 keV (figure.5& 6) supplied by Health Physics Division, Atomic Energy Centre, Dhaka (AECD) and following standard method. The unknown efficiencies of different radionuclides were then calculated using Eq. (1).

$$\text{Efficiency} = \frac{net\ \ counts\, per\ \text{second}}{P_\gamma \cdot A} \text{ X } 100\% \text{---------(1)}$$

where P_γ = the fraction of number of gamma-rays emitted from a particular radionuclide,
A= activity of the radionuclide present in the samples.

The radioactivity concentrations of different radionuclides were based on the measured detector efficiencies (for corresponding radionuclides) as a function of energy curve for same counting geometry and time. Thus using the measured efficiencies of the radionuclides, the activities of the measured radionuclides were calculated with the following equation:

$$\text{Activity (A)} = \frac{\text{Net cps} \times 100 \times 1000}{\text{Eff} \times P\gamma \times 50.97} \text{ in } mBq/m^3 \text{ ------ (2)}$$

Where, C = net counts per second
Eff = efficiency of the detector at that energy E(keV) of the peak measured earlier.
$P\gamma$ = the photon energy emission probability at energy E (keV).
50.97 = total flow of air in one hour

Error Analysis
Experimental observations may be inaccurate due to systematic and random errors. The systematic errors can be minimized by employing sophisticated equipment and techniques and by improving personal skill. Random errors can also be reduced but cannot be eliminated. Hence, in order to complete and interpret experimental data and results, it is necessary to find the extent of the error associated with the analysis of samples. However, with the knowledge of the statistical behavior of error in observation i.e. deviation from normal value, it is possible to reduce the effect of errors of the final result. The error calculation was done by the following formula

$$\sigma = \sqrt{\frac{S+B}{T^2} + \frac{B}{T^2}}$$

Where, S+B = total sample with background counts
B = total background counts
T = time in seconds.
The error activity was done by the following formula:

$$\text{Error activity} = \frac{\sigma \times 100 \times 1000}{\text{Eff} \times P\gamma \times 50.97} \ [mBq/m^3]$$

σ = error
$P\gamma$= the photon energy emission probability at energy E (keV).
Eff = Counting efficiency at the desired energy of the radio nuclides.

RESULT & DISCUSSION
The main sources of natural background radiation are radioactive substances in the earth's crust, emanation of radioactive gas from the earth, cosmic rays from outer space. Natural radionuclides ^{212}Pb, ^{214}Pb, ^{214}Bi, ^{228}Ac and ^{40}K were found in air samples during measurement of air filter. The activity concentrations of ^{212}Pb,^{214}Pb,^{214}Pb, ^{214}Bi,^{228}Ac, ^{228}Ac, $^{214}Bi$and ^{40}K were determined directly by

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measurement of the gamma-ray transitions at 238.6 keV, 295.21 keV, 351.92keV, 609.31 keV, 911.07keV, 969.11 keV, 1120.29 keV and 1460.81 keV respectively. Artificial radionuclide was not observed in this study. The radioactivity ranges from Minimum Detection Activity (MDA) mBq/m^3to295±5.986mBq/m^3 for Pb- 212 and its average value is 132.647±0.483mBq/m^3. It is a member of Thorium-232 decay series. This can escape from the soil and ascend into the air. The presence of Pb-212 in atmospheric dust particles and virtually all other types of geological materials and the smoke of the vehicles are the most probable reason of finding activity in air of Gabtoli Bus Terminal. But at Mirpur Beribadh there is no existence of Pb-212.Because it is less dense area. A lot of tress is seen in this area. Mills and factories are not available here. These are the most probable reason of absence of Pb-212. The radioactivity ranges from 0.0mBq/m^3 to 1910.88±12.311mBq/m^3 for Pb-214 and its average value is 363.920±1.209mBq/m^3.It is a member of Uranium-238 decay series. Pb-214can attach to dust and other particles which is the most probable reason forgetting Pb-214 in air sample due to the rate of abrupt increase of vehicles in Dhaka city containing Pb-214 in the fuel used. At Mirpur Beribadh we get high activity of Pb-214 in air sample. Highway road goes beside the Mirpur Beribadhand a lot of vehicles are driven through this highway that emits Pb-214, it is the most probable reason of finding Pb-214. The radioactivity ranges from 0.0mBq/$m^3$to 2192.32±12.795 mBq/m^3 for Bi-214 and its average value is501.616±2.535 mBq/m^3.

It is a member of Uranium-238 decay series. Bi-214 can be found in variety of chemical as many pharmaceuticals shops are present around theMeradia Bus Stand. This could be the one of the reasons of high activity of Bi-214.Since it may be present in materials quarried from the earth crust used in the production of cement and its major use in building industries and various construction may be the most probable reason of high activity of Bi-214. There are many buildings near Meradia Bus Stand. But at Mirpur Beribadh there is no existence of Pb-214, because it is less dense area. A lot of trees are seen in this area. Mills and factories are not available here. These are the most probable reason of absence for the Bi-214. The radioactivity ranges from 0.0mBq/m^3 to 570.77±1.137mBq/m^3 for Ac-228 and its average value is 53.608±0.727mBq/m^3. It is produced by the radioactive decay, or breakdown, of uranium and other unstable elements. Naturally occurring actinium is very rare in the Earth's crust. Actinium can be artificially produced. Around Rampura there are a lot of pharmaceuticals industries which may be the reason of getting Actinium. A Statistical representation of the concentration of Pb-212, Pb-214, Ac- 228, Bi-214 and K-40 for different filter papers has been shown in figure 7.

The activity concentrations of ^{238}U and ^{232}Th for both regions were measured from the average concentration of nuclides [^{214}Pb (295.21keV), ^{214}Pb (351.92keV), ^{214}Bi (609.31keV), ^{214}Bi (1120.29keV)], [^{212}Pb (238.63keV), ^{228}Ac (911.07keV) and ^{228}Ac (969.11keV)] respectively. The activity concentration values quoted assume secular equilibrium for the different isotopic activities in the decay chains. The radioactivity of ^{238}U, ^{232}Th and ^{40}K have been presented in table 2. The activity concentration of ^{238}U ranges from 3.92±5.04 mBq/m^3 to 1784±6.87 mBq/m^3 and its average value is 447.77±1.61 mBq/m^3. Activity concentration of ^{232}Th ranges from MDA to 398±0.70 mBq/m^3 and its average value is 90.71±0.86 mBq/m^3. Activity concentration of ^{40}K ranges from MDA to 256±3.81 mBq/$m^3$and its average value is 92.66±3.54 mBq/m^3. The radioactivity of Potassium-40(K-40) is higher than others radionuclides because K-40 is a naturally-occurring radionuclide and is present in the crust of the Earth since its creation. We find it abundantly at Zia Uddan. Beside Zia Uddan there are lots of high storied Building that used cement and tilling materials for construction. This is the most probable reason for finding K-40. But at Baldah Garden, there is no existence of K-40. Baldhah Garden is situated in residential area which is pollution free in comparison to other location. There is a plenty of trees around the garden. This is the most probable reason for the absence K-40.

CONCLUSION

A determination of the concentration and the distribution of air particle radioactivity are essential in establishing reference data, allowing

the observation of possible changes due to radiological contamination. The main purpose of the present research is to measure the concentrations of different radionuclides in air particle of air sample which is helpful to establish the base line data. In Bangladesh, the constructions of nuclear power plant have also been started. Rooppur is almost near the Dhaka city. So the concentrations of different radionuclides in air particle of present study will be helpful to monitor and compare the concentration of radionuclides in air samples around Rooppur Nuclear Power Plant (RNPP) project. After the accident of Fukushima, the radioactivity of air particle was measured and compare with its previous data. India is the neighboring country which has nuclear power plant so there is lot of chance to contaminate the air. To establish the base line data, it will useful to monitor and measure concentration of radionuclides in air particles.

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Table no,1: Different Places of Dhaka city for sample study

Name of the place	Sample ID	Name of the place	Sample ID
Fulbaria Bus Stand	Filter paper 1	Dhanmondi Lake	Filter paper 21
Tannery Area	Filter paper 2	Zia Uddan	Filter paper 22
Plastic Goli,Islambagh,lalbagh	Filter paper 3	Mirpur Beribadh	Filter paper 23
Mirpur 14 Bus Stand	Filter paper 4	Baldah Garden	Filter paper 24
Matikata,Cantonment	Filter paper 5	Rampura	Filter paper 25
Mirpur 10 GolChakkar	Filter paper 6	Baddha	Filter paper 26
Matuail, Jatrabari	Filter paper 7	National Botanical Garden	Filter paper 27
Signboard, Demra	Filter paper 8	Bangladesh National Zoo	Filter paper 28
Sayedabad Bus Terminal	Filter paper 9	Mirpur 12 Cantonment	Filter paper 29
Shadorghat Bus Terminal	Filter paper 10	Motijheel	Filter paper 30
Char Kaligong	Filter paper 11	Farmgate	Filter paper 31
Banani	Filter paper 12	Kallyanpur Bus stand	Filter paper 32
Mohakhali	Filter paper 13	Mirpur 1 Bus Stand	Filter paper 33
Fakirapul	Filter paper 14	Mirpur 12 Bus Stand	Filter paper 34
Gabtoli	Filter paper 15	Kazipara Bus Stand	Filter paper 35
Mouchak	Filter paper 16	Azimpur Bus Stand	Filter paper 36
Mogbazar	Filter paper 17	Mohammadpur Bus stand	Filter paper 37
Kalshi	Filter paper 18	Curzon Hall, Dhaka University	Filter paper 38
Banasree	Filter paper 19	Ramna Park	Filter paper 39
Meradia Bus Stand	Filter paper 20	Mirpur DOHS	Filter paper 40

Table no,2. The Radioactivity of ^{238}U, ^{232}Th and ^{40}K in different Filter paper of different places

Name of place	No. of Sample	Radioactivity of ^{238}U (mBq/m^3)	Radioactivity of ^{232}Th (mBq/m^3)	Radioactivity of ^{40}K (mBq/m^3)
Fulbaria Bus Stand	Filter Paper 1	596±6.62	77.85±2.27	29.55±11.48
Tannery Area	Filter Paper 2	752±0.96	142±0.44	128±3.72
Plastic Goli, Islambagh	Filter Paper 3	1334±1.25	148±0.47	78.78±3.76
Mirpur 14 No Bus Stand	Filter Paper 4	388±0.72	48.14±0.39	98.49±3.70
Matikata,Cantonment	Filter Paper 5	42.07±0.36	54.52±0.39	MDA
Mirpur 10 No. GolChakkar	Filter Paper 6	46.76±0.39	34.23±0.08	88.63±3.70
Matuail, Jatrabari	Filter Paper 7	374±0.72	83.5±0.12	9.85±3.64
Signboard, Demra	Filter Paper 8	499±0.80	88.28±0.42	59.09±3.68
Sayedabad Bus Terminal	Filter Paper 9	814±0.98	164±0.48	207±3.78
Shadorghat Bus Terminal	Filter Paper 10	507±0.81	48.91±0.39	19.69±3.65
Char Kaligong	Filter Paper 11	654±0.9	86±0.121	226 ±3.79
Banani	Filter Paper 12	221±0.58	2515±0.56	88.63±3.69
Mohakhali	Filter Paper 13	238±0.60	53±0.1	147±3.73
Fakirapul	Filter Paper 14	3.92±5.04	0.29±0.97	MDA
Gabtoli	Filter Paper 15	636±17.56	163±18.903	MDA
Mouchak	Filter Paper 16	287±0.64	56.48±0.10	49.24±3.66
Mogbazar	Filter Paper 17	272±0.63	50.09±0.39	128±3.72
Kalshi	Filter Paper 18	87.75±0.45	16.21±0.06	49.24±3.66

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Banasree	Filter Paper 19	144±0.51	95.99±0.41	157±3.74
Meradia Bus Stand	Filter Paper 20	1784±6.87	133±0.454	128±3.72
Dhanmondi Lake	Filter Paper 21	501±0.65	127±0.44	59.09±3.67
Zia Uddan	Filter Paper 22	623±0.88	110±0.47	256±3.81
Mirpur Beribadh	Filter Paper 23	955±6.15	MDA	MDA
Baldah Garden	Filter Paper 24	1352±1.25	131±0.46	MDA
Rampura	Filter Paper 25	657±0.90	398±0.70	78.79±3.68
Baddha	Filter Paper 26	440±0.76	61.94±0.10	147±3.73
National Botanical Garden	Filter Paper 27	392±0.01	114±0.06	98.49±0.05
Bangladesh National Zoo	Filter Paper 28	123±0.43	118±0.39	78.79±3.68
Mirpur 12 Cantonment	Filter Paper 29	274±0.431	105±0.39	108±3.68
Motijheel	Filter Paper 30	483±0.79	113±0.44	68.94±3.68
Farmgate	Filter Paper 31	283±0.63	16.12±0.47	157±3.74
Kallyanpur Bus stand	Filter Paper 32	106±0.43	59±0.10	108±3.70
Mirpur 1 Bus Stand	Filter Paper 33	106±0.38	59±0.09	108±3.64
Mirpur 12 Bus Stand	Filter Paper 34	34.305±0.45	39.665±0.53	19.69±3.78
Kazipara Bus Stand	Filter Paper 35	535±0.56	89.5±0.11	221±3.750
Azimpur Bus Stand	Filter Paper 36	295±0.53	26.76±0.31	157±3.74
Mohammadpur Bus stand	Filter Paper 37	145±0.42	55.97±0.28	78.79±3.68
Curzon Hall, Dkaka University	Filter Paper 38	663±0.36	85.77±0.42	29.54±3.65
Ramna Park	Filter Paper 39	55.98±0.41	25.80±0.37	118±3.71
Mirpur DOHS	Filter Paper 40	192±0.42	93.43±0.52	29.55±11.47
	Average	447.77±1.61	90.71±0.86	92.66±3.54

Figure1. Study area (Ramna, Motijheel)

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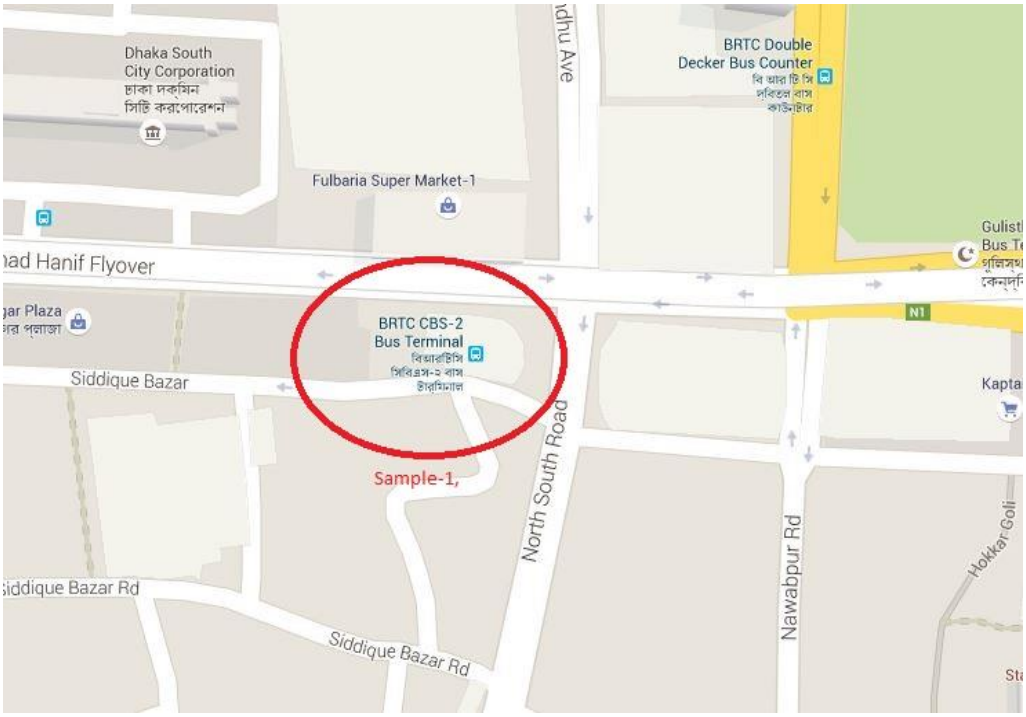

Figure 2. Study area (BRTC Bus Terminal)

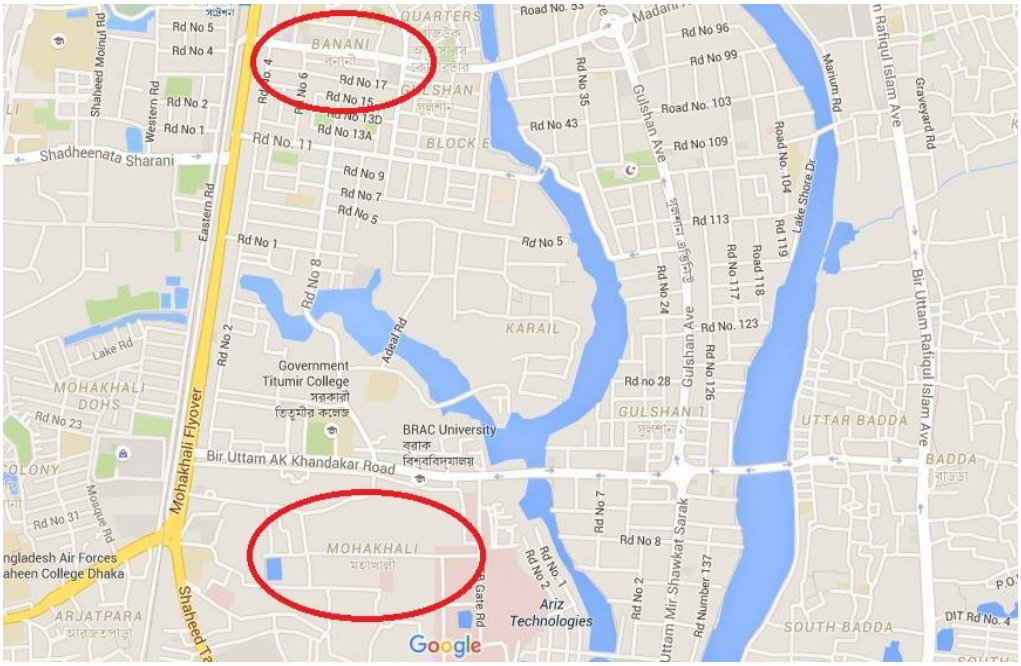

Figure 3. Study area (Mohakhali, Banani)

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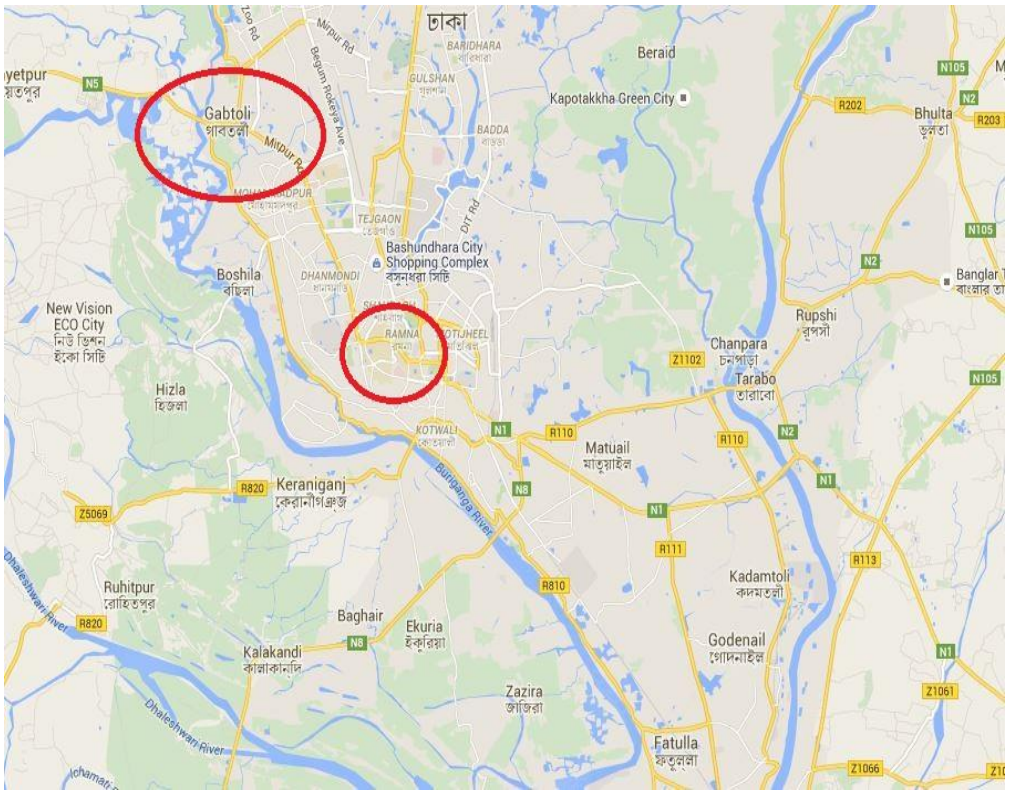

Figure 4: Study area (Gabtoli)

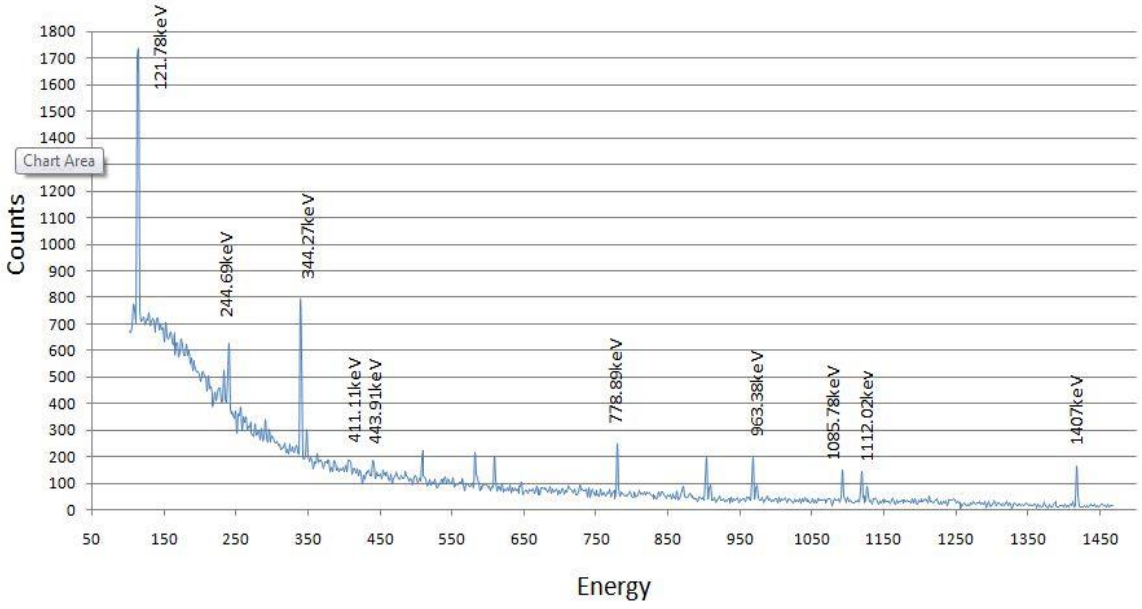

Figure 5.Gamma Energy Spectrum of Eu-152

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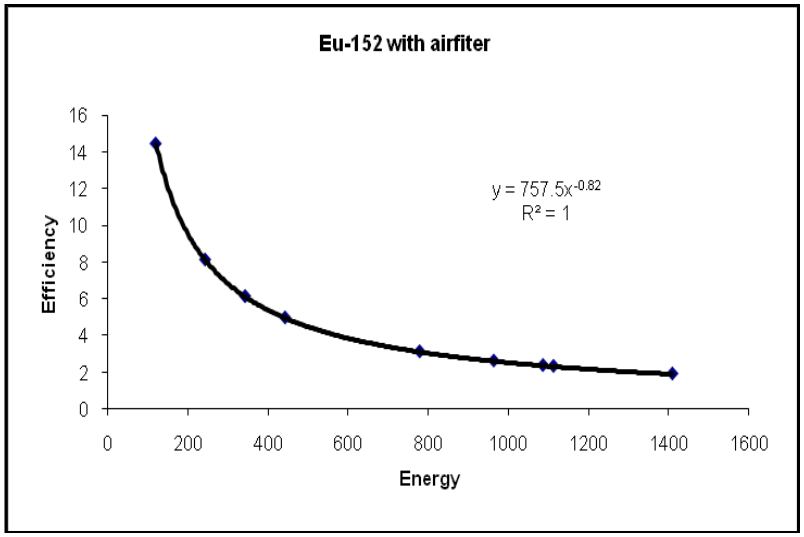

Figure 6. Efficiency (%) curve of the HPGe detector

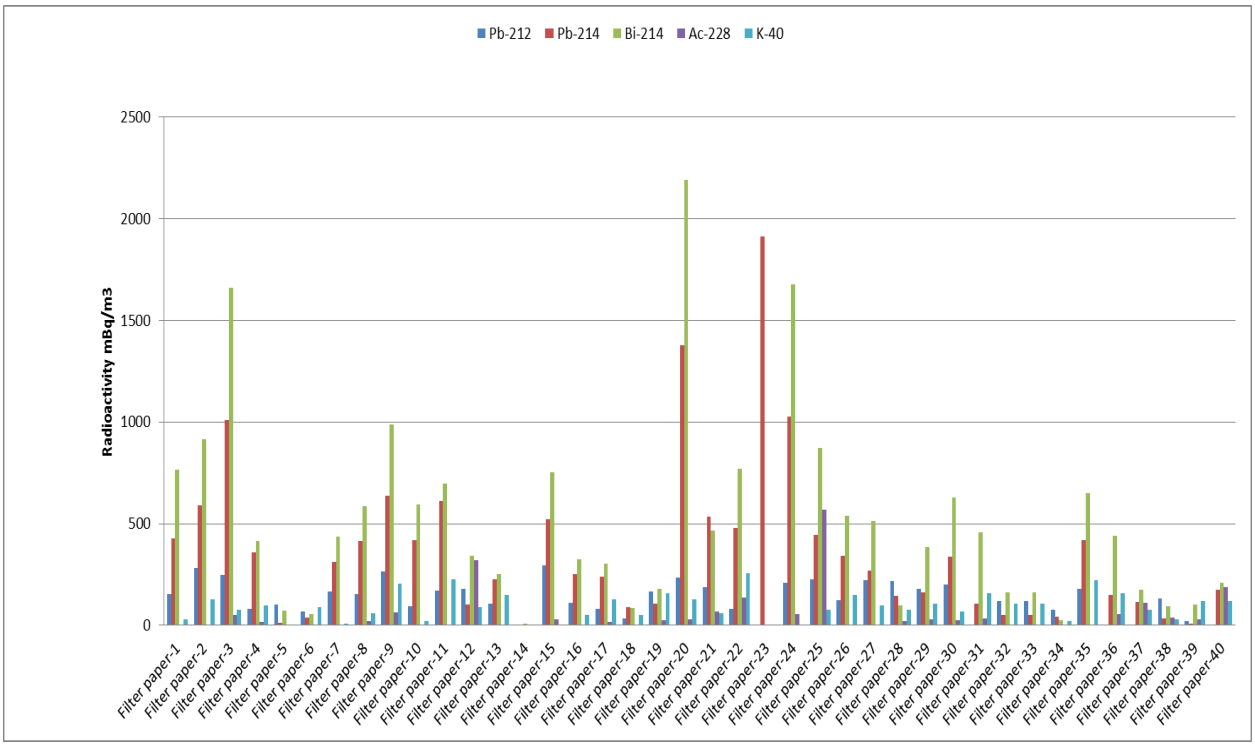

Figure: 7. A Statistical representation of the concentration of Pb-212, Pb-214, Ac- 228, Bi-214 and K-40 for different filter papers